AMENDMENTS TO THE SPECIFICATION

Please replace Paragraphs [0015], [0020], [0021], [0024], [0026], [0028] [0030], [0031], [0036], [0040], [0041], [0042], [0043], [0044], [0046] [0047], [0048], [0049], [0052], [0053] [0058], [0060], [0062], [0069], and [0070] with the following paragraphs rewritten in amendment format:

[0015] Figure 5 is a combustor accordingly to <u>an</u> alternative embodiment;

[0020] The following description of various embodiments is merely exemplary in nature and is in no way intended to limit the ~~invention~~ <u>present disclosure</u>, its application, or uses. Specifically, although the following combustor is described in conjunction with a terrestrial gas powered turbine, it may be used in other systems. Furthermore, the mixer and heat exchanger may be used in systems other than turbine systems.

[0021] Referring to Figure 1, a gas powered turbine in accordance with ~~a preferred~~ <u>an</u> embodiment of the present ~~invention~~ <u>disclosure</u> is shown. The gas powered combustion turbine 10 may use several different liquid or gaseous fuels, such as hydrocarbons (including methane, propane and natural gas), hydrogen, and Synthesis gas that are combusted and that expand to move portions of the gas powered turbine 10 to produce power. An important component of the gas powered turbine 10 is a compressor 12 which forces atmospheric air into the gas powered turbine 10. Also, the gas powered turbine 10 includes several combustion chambers 14 for combusting fuel. The combusted fuel is used to drive a turbine 15 including turbine blades or fans 16 which are axially displaced in the turbine 15. There are generally a plurality of

turbine fans 16, however, the actual number depends upon the power the gas powered turbine 10 is to produce. Only a single turbine fan is illustrated for clarity.

[0024] The gases which are exhausted from the gas powered turbine 10 include many different chemical compounds that are created during the combustion of the atmospheric air in the combustion chambers 14. If only pure oxygen and pure hydrocarbon fuel[[,]] were combusted, absolutely completely and stoichiometrically, then the exhaust gases would include only carbon dioxide and water. Atmospheric air, however, is not 100% pure oxygen and includes many other compounds such as nitrogen and other trace compounds. Therefore, in the high energy environment of the combustion chambers 14, many different compounds may be produced. All of these compounds exit the exhaust port 18.

[0026] It will <u>also</u> be understood that the gas powered turbine 10 may include more than one combustion chamber 14. Any reference to only one combustion chamber 14, herein, is for clarity of the following discussion alone. The <u>system and method of the</u> present ~~invention~~ <u>disclosure</u> may be used with any oxidizer or fuel which is used to power the gas powered turbine 10. Moreover, the combustor 14 may combine any appropriate fuel. Air is simply an exemplary oxidizer and hydrocarbons an exemplary fuel.

[0028] With further reference to Figure 2, a plurality of heat exchange or catalyst tubes 48 extend into the heat exchange area 32. The heat exchange tubes 48 are spaced laterally apart. The heat exchange tubes 48, however, are not spaced vertically apart. This configuration creates a plurality of columns 49 formed by the heat exchange tubes 48. Each heat exchange tube 48, and the column

49 as a whole, define a pathway for air to travel through. The columns 49 define a plurality of channels 50. It will be understood this is simply exemplary and the tubes 48 may be spaced in any configuration to form the various pathways. Extending inwardly from the walls of the heat exchange chamber 33 may be directing fins (not particularly shown). The directing fins direct the flow of air to the top and the bottom of the heat exchange chamber 33 so that air is directed to flow vertically through the channels 50 defined by the heat exchange tubes 48.

[0030] Air which exits out the heat exchange tubes 48 is entrained with fuel injected from an injector port 60, according to various embodiments[[,]] that being the main injector 52, and this fuel then combusts in the main combustion section 34. The main combustion section 34 directs the expanding gases of the combusted fuel to engage the turbine fans 16 so that the expanded gases may power the turbine fans 16.

[0031] Turning reference to Figure 3, a detailed portion of the heat exchanger 45 is illustrated. Although, in one embodiment, the heat exchanger 45 includes a large plurality of tubes, as generally shown in Figure 2, only a few of the heat exchange tubes 48 and cooling tubes 44 are illustrated here for greater clarity. The heat exchanger 45 may be similar to the heat exchanger described in U.S. Patent No. 5,309,637 entitled "Method of Manufacturing A Micro-Passage Plate Fin Heat Exchanger", incorporated herein by reference. The heat exchanger 45 includes a plurality of cooling tubes 44 disposed parallel to and closely adjacent the heat exchange tubes 48. Each of the cooling tubes 44 and the heat exchange tubes 48 have a generally rectangular cross section and can be made of any generally good thermally

conductive material. Preferably, the heat exchange tubes 48 and the cooling tubes 44 are formed of stainless steel. It will be appreciated that while the cooling tubes 44 and the heat exchange tubes 48 are shown as being substantially square, the cross-sectional shape of the components could comprise a variety of shapes other than ~~squares~~ a square shape. It is believed, however, that the generally square shape will provide the best thermal transfer between the tubes 44 and 48.

[0036] With continuing reference to Figures 1-3 and further reference to Figure 4, a method of using the combustion chamber 14 according to various embodiments will be described. The combustor 14 includes a pre-mixer 42 which may be formed in any appropriate manner. The pre-mixer 42 may include an open region, as illustrated in Figure 4, or may include a plurality of the cooling tubes 44 (not particularly illustrated). When an open region is used as the pre-mixer 42 the flow generally follows the path indicated by the arrows in Figure 4. It will also be understood that a plurality of tubes, as described above, are present in the heat exchanger 45, but have been removed for clarity in the present description of the air flow. Atmospheric air is compressed in the compressor 12 and then introduced into the heat exchange chamber 33 at a high pressure. The air that enters the heat exchange chamber 33 is directed by the directing fins to the top and bottom of the heat exchange chamber 33 so that the air may flow through the channels 50. The air that enters the heat exchange chamber 33 may be at a temperature of about 37° C to about 427° C (about 100° F and about 800° F). Generally, however, the air enters the heat exchanger 45 at a temperature of about 204° C to about 400° C (about 400° F to about 750° F).

[0040] The selected oxidizer and a first portion of the fuel is mixed in the pre-mix section 72, in an area of overlap or heat exchange that is formed where the cooling tubes 44 overlap the heat exchange tubes 48 in an overlap section 82. Although the shape of the combustor 70 may be different than the shape of the combustor 14 illustrated in Figure 2, the purpose and operation may be substantially similar. Nevertheless, the main injector plate 78 may be easily removed from the combustor assembly 70 due to a local main fuel injection port 84. The main fuel line 38 is interconnected to the main injector plate 78 through the fuel supply port 84. Therefore, rather than supplying the fuel through the center of the combustor 70, the fuel is provided near the main ~~injection~~ <u>injector</u> plate 78 for easy removal of the main injector plate 78.

[0041] With continuing reference to Figure 5 and additional reference to Figure 6, where in Figure 6 the outer portion of the combustor 70 has been removed to illustrate in detail the main injector plate 78. The main injector plate 78 defines a plurality of oxidizer pathways 86 through which the heated oxidizer flows from the heat exchange tubes 48. The heated oxidizer flows into the main combustion area 76 which is defined as the area downstream of the downstream face 78a of the main injector plate 78. Fuel is provided to the areas between the oxidizer pathways 86 through a plurality of injector plate fuel pathways 88. The main injector plate fuel pathways 88 extend from the fuel <u>supply</u> port 84 to the areas between the oxidizer pathway 86 to injectors or an injector element 90, as described herein.

[0042] With continuing reference to Figure 6, the main injector plate 78 defines a plurality of the main injector plate fuel pathways 88 such that fuel may be

provided to each of a plurality of areas between the oxidizer pathways 86. The main injector plate 78 defines a thickness appropriate to supply the fuel to the injection areas. The thickness of the main injector plate 78 may be any appropriate thickness to meet various requirements. Nevertheless, the main injector plate 78 provides the final pathway for the fuel as it flows to the injector areas to be injected into the combustion area 76.

[0043] Because the fuel supply port 84 is interconnected with the main injector plate ~~76~~ 78, the main fuel line 38 may be disconnected and the main injector plate 78 removed from the combustor assembly 70. This may be done for any appropriate reason, such as cleaning the injectors in the main injector plate 78, changing the injectors in the injector plate 78, or any other appropriate reason. Therefore, the heat exchange tubes 48 may not generally be fixed to the main injector plate ~~76~~ 78, but rather fixed to a seal or second portion that is able to substantially seal with or engage the main injector plate 78 such that the oxidizer[[s]] is provided in the appropriate area.

[0044] With reference to Figure 7, the main injector plate 78 defines ~~a~~ the plurality of ~~oxidized~~ oxidizer pathways 86 relative to which a plurality of injectors in an injector element 90 is provided. The injector element 90 generally extends along a length that is provided near a plurality of the oxidizer pathways 86. Provided in the injector element 90 is an injector slot 92 that extends from an orifice 94. Fuel is provided from or through the injector orifice 94 to the injector slot 92. The slot 92, as described herein, assists in forming a fuel fan or fuel spray 96 relative to one of the oxidizer pathways 86. The injector element 90 may provide a plurality of the injector

slots 92 and injector orifices 94 for each of the oxidizer pathways 86, or only one slot 92 per pathway 86 may be provided. Nevertheless, the injector element 90 is able to provide the fuel fan 96 to at least one of the selected oxidizer pathways 86.

[0046] Once the fuel is provided to the fuel feed cavity 98 under a selected pressure, the fuel moves towards and through the injector orifice 94 into the injector slot 92. The fuel fan 96 is formed as a fuel jet 100 exits ~~to~~ the orifice 94 from the fuel feed cavity 98. The fuel jet 100 generally engages a downstream ~~or~~ splash plate ~~portion~~ 102 of the injector element 90 and ~~in a~~ is spread across the splash plate ~~or splash face~~ 102. As the fuel is spread across the splash ~~face~~ plate 102, the fuel spreads out such that it exits the injector slot 92 in a substantially open or fanned form.

[0047] A coolant pathway 104 is provided through a nose or downstream end 106 of the injector element 90. In addition, the very tip or end of the nose 106 may be a ~~substantial~~ substantially flat or planar surface 108, for reasons described herein. In addition, a removable plug 110 may be used to seal or close a selected side of the fuel feed cavity 98 such that the fuel feed cavity plug 110 may be easily removed for selected purposes.

[0048] With continued reference to Figure 8, the injector orifice 94 may be any appropriate size, and ~~is~~ may be about 0.001 to about 0.1 inches (about 0.254 mm to about 2.54 mm). The injector orifice 94, however, may be any appropriate size or shape. For example, the injector orifice 94 may be a selected geometrical shape, such as an octagon, or other appropriate polygon. In addition, the injector orifice 94 may be a slot substantially equal to the injector slot 92 provided in the injector element 90. Therefore, the injector orifice 94 need not simply be circular or round in

shape and size, but may be any appropriate size to provide the fuel jet 100 through the injector orifice 94 to engage the splash plate 102. In addition, the length of the orifice 94 may be any appropriate length. Nevertheless, it may be provided to include a length to diameter ratio (L/D) of about zero to produce a substantially free jet of fuel 100. Therefore, the fuel jet 100 may nearly immediately impinge the splash plate 102 to form the fuel fan 96.

[0049] In addition, the ~~fuel~~ <u>injector</u> slot 92 generally includes a width C that is not substantially filled by the pre-fuel fan 96a. The pre-fuel fan 96a formed within the slot 92 generally fills less than about 90% of the width C of the injector slot 92, but <u>it</u> may ~~be~~ <u>fill</u> any appropriate amount of the width<u>,</u> such as about 10% ~~may be~~ <u>of the width</u>. According to various embodiments, the ~~fuel~~ <u>injector</u> slot <u>92</u> width C may be greater than about 0.02 inches (about 0.508 mm). For example, when the fuel jet 100 exits the orifice 94, it is generally not greater than about 0.02 inches. The hydraulic diameter of the fuel jet 100 is about 0.005 inches to about 0.01 inches (about 0.127 mm to about 0.254 mm). Therefore, the fuel jet fills, according to this example, at most 50% of the <u>injector</u> slot 92.

[0052] With continuing reference to Figures 8 and 9, the injector element 90 includes a plurality of the orifices 94 and <u>the injector</u> slots 92. As particularly illustrated in Figure 7, the slots 92 may alternate on the injector element 90 such that the injector element 90 is able to provide the fuel fan 96 to an alternating one of the oxidizer pathways 86 on either side of the injector element 90. Although it will be understood that providing the alternating pathways is not necessary, this may provide a ~~substantial~~ <u>substantially</u> efficient manner of providing fuel to each of the oxidizer

pathways 86. Nevertheless, it will be understood that one injector slot 92 need not be provided to each of the oxidizer pathways 86. Rather, fuel may be provided through the injector slot 92 such that it expands to provide fuel to a plurality of the oxidizer pathways 86 rather than to only one of the oxidizer pathways 86.

[0053] ~~It is a~~ As merely an example, and not intended to be limiting, the injector element 90 may provide a fuel fan 96 that has a velocity of about 180 to about 330 feet per second (about 54.86 meters per second to about 100.58 meters per second). Generally, this provides a sheet velocity exiting the injector orifice 92 of about 45 to about 80 feet per second (about 13.72 to about 24.38 meters per second) with a sheet thickness of approximately 0.005 inch to 0.010 inch (about 0.127 mm to about 0.254). Generally, the heated oxidizer that exits the oxidizer pathway 86 generally has velocity of about 200 to 300 feet per second (about 60.96 to about 91.44 meters per second). Therefore, it is expected that the fuel fan will first penetrate about 0.04 inches to about 0.06 inches (about 1.02 mm to about 1.524 mm) or about 40% of the width of an exemplary 0.125 inch (3.175 mm) oxidizer pathway ~~channel~~ 86. In addition, turbulent eddy diffusion may also cause the fuel jet to mix with the hot vitiated air stream. Calculations to determine the jet penetration distance and subsequent eddy diffusion fuel mixing times are generally known in the art such as those described in Rudinger, G., AIAA Journal 12 (No. 4) 566 (1974) and Williams, F.A., Combustion Theory, Addison-Wesley, Reading, MA (1965). With the above information, it may be expected that the fuel may be substantially mixed with the heated oxidizer in approximately 1 millisecond. Therefore, although merely exemplary, the injector element 90 is able to substantially mix fuel with the heated oxidizer that is emanating

from the oxidizer pathway 86 before the fuel is able to reach the auto ignition temperature and combust. Therefore, the fuel will be able to substantially combust evenly across the face 78a of the injector plate 78 such that no substantial hot spots are created. Generally, substantial mixing before combustion may allow the fuel to combust evenly across the face 78a without the face exceeding selected temperatures below about 1700 °F (about 927 °C).

[0058] The use of two fuels may be used with substantially little difficulty in a single system. For example, and not intended to limit the description, a selected fuel may be natural gas, which may be used as a general and operating fuel, while hydrogen gas may be used as a start-up fuel. During the start-up phase, the gaseous hydrogen may react with the other portions of the gas powered turbine 10 in a substantially similar manner as the natural gas. For example, the hydrogen may be able to mix with the hypergolic air by being injected through the main injector plate 52 in a manner such that the gaseous hydrogen does not produce results that are dissimilar to other selected fuels. For example, a fuels injection momentum, G_f (ft.-lbm/sec$_2$), at a given heating rate, is defined by the following equation:

$$G_f \propto \frac{\hat{M}_f}{P\,\Delta H_{c,f}^{\;2}} \qquad (1)$$

where P is the main combustor compressor pressure (psi), $\cancel{\hat{M}_f}$ $\hat{M}_f$ is the molecular weight of the fuel (grams/mol) and $\Delta H_{c,f}$ is the fuel's molar or volumetric heat of combustion (BTU/SCF).

[0060] Selected fuels may be substantially mixed with the heated oxidizer before the fuel combusts using the injector <u>element</u> 90. Fuels that have substantially

equivalent fuel injection momentums, as defined by Equation 1, may be used in similar injectors without changing the injector geometry. Therefore, according to the example described above where natural gas and hydrogen ~~has~~ have substantially similar injector momentums, the injector will mix the fuel in a substantially similar manner.

[0062] Thus, it will be understood that hydrogen need not simply be a start up fuel, and may be a fuel used to operate the combustor 14 during operation. That is a methane fuel source may be available at a certain point in the operating cycle of the combustor and/or a hydrogen fuel source is available during a different operating cycle of the combustor 14. Either of the fuels could be used to operate the combustor 14 without changing any of the portions of the combustor 14. Simply, [[a]] different fuels may be run through the combustor 14.

[0069] Channels 150 are still provided between each of the catalyst fins 148 so that air may flow from the compressor through the cooling fins 144 into the premix chamber 142. Air is then premixed with a first portion of fuel and flows back through the catalyst fins 148 to the main injector plate 152. Injection ports 160 are provided on the main injector plate 152 to inject fuel as the air exits the catalyst fin 148. A suitable number of ~~injection~~ injector ports 160 are provided so that the appropriate amount of fuel is mixed with the air as it exits the catalyst fins 148. An intra-propellant plate 54 is also provided.

[0070] The [[I]]injector ports ~~60 or 90 are still~~ 160 provided on the main injector plate 152 ~~to~~ provide fuel stream[[s]] ~~76 or 92~~ as heated air exits the oxidizer paths (not particularly shown) from the catalyst fins 148. Either of the previously described injector ports 60 or 90 may be used with the second embodiment of the heat

exchanger 145 to provide a substantial mixing of the fuel with the air as it exits the catalyst fins 148. This still allows a substantial mixture of the fuel with the air as it exits the catalyst fins 148 before the fuel is able to reach its ignition temperature. Therefore, the temperatures across the face of the main injector 152 and in the combustion chamber 34 are still substantially constant without any hot spots where NOX chemicals might be produced.